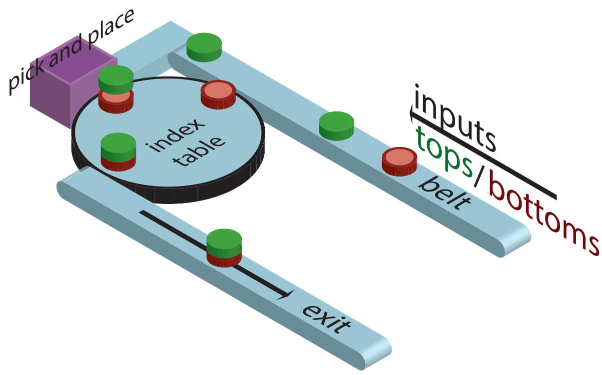
Electrical Engineering – Electronic Systems

Midterm Exam Electronic Systems Engineering – 5XIC0 – Practice

last name: ______________________ initials: ________ student id: ____________

A simple manufacturing machine

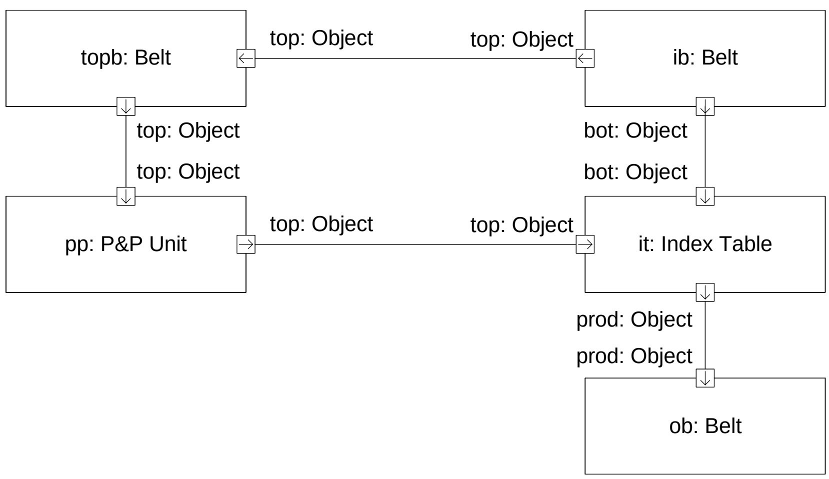
Throughout this exam, we consider a simple manufacturing system. The base manufacturing machine has the following layout.



The machine takes two kinds of objects on the input conveyor belt. We call those types of objects 'bottoms' (shown as red objects) and 'tops' (shown as green objects) and the purpose of the system is to combine them into a combined product by placing the tops on the bottoms. The bottoms and tops are fed into the system alternatingly, starting with a top. Tops are transported by conveyor belts to a pick-and-place unit. Bottoms are transported on the conveyor belt to a rotating index table, which will rotate it towards the pick-and-place unit that will place the top on top of it. The combined product is transported by the index table to another conveyor belt, which will move the object to the system output.

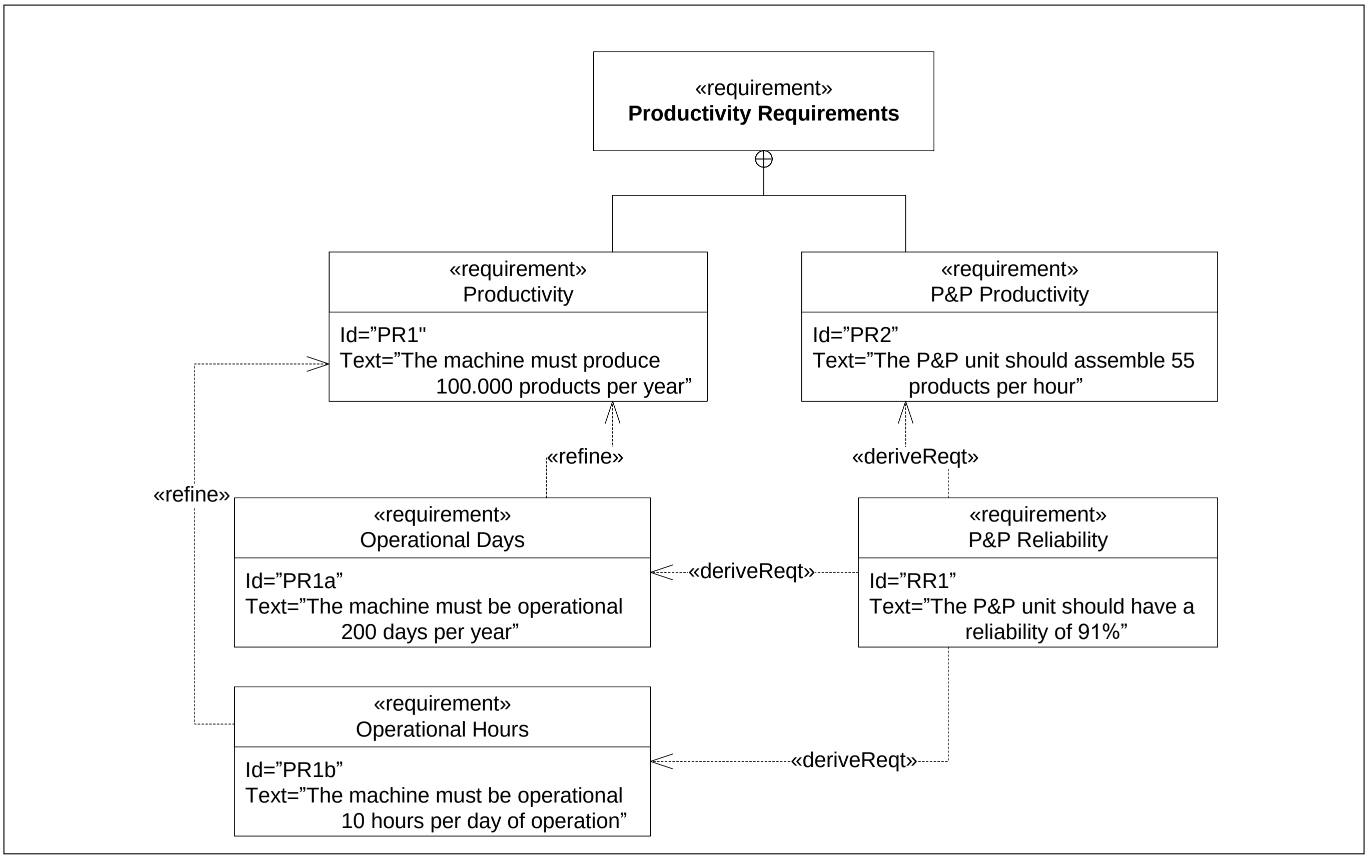
(10 points) Question 1 – Internal Block Diagram

The manufacturing machine is built from a number of components, namely belts, an index table, and a pick-&-place unit. Assume we have defined a block 'Machine' representing the manufacturing machine. Draw an internal block diagram that represents the structure of the machine and the flow of objects through the machine, where two components A and B are connected if and only if objects (bottoms, tops, or full products) can flow from A to B (directly, without going through another component).



(10 points) Question 2 – Requirements

We are planning a production facility with a single machine that is responsible for the full production of 100.000 products per year. The machine is expected to be operational 200 days per year and 10 hours per day. Assume that the pick-&-place unit can assemble 55 products per hour. Assembly is not perfect. Tops and bottoms may be misaligned. Misaligned products need to be discarded. Give a requirements diagram that captures the main requirement on the productivity of the system, its refinement in terms of the availability of the machine, and a derived requirement on the reliability of the pick-&-place unit (in terms of a percentage of successfully assembled products per hour).

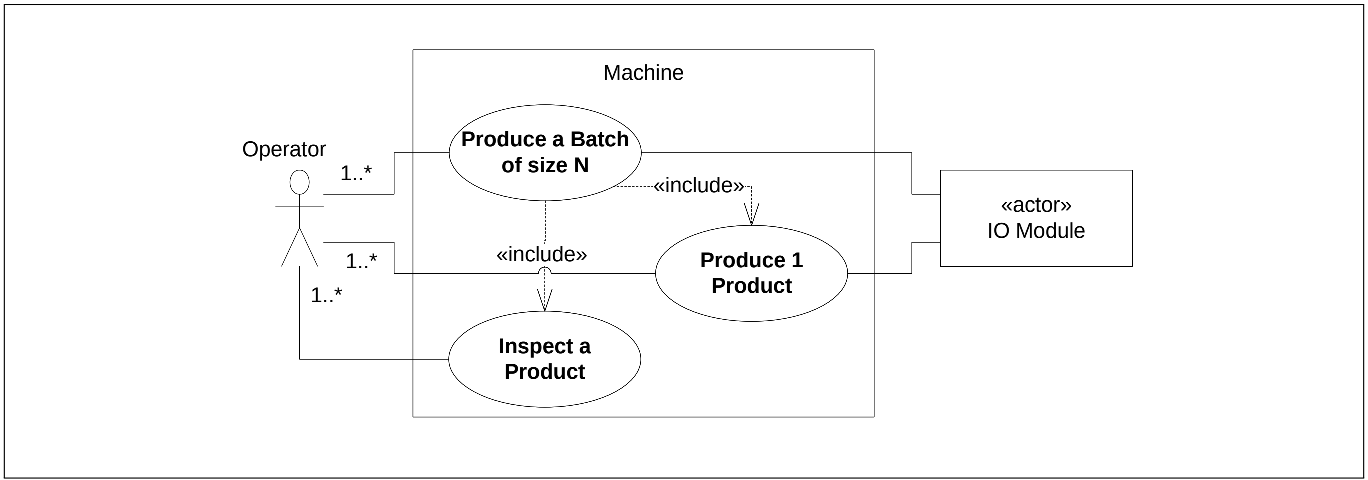


Producing a Batch of Products

The base manufacturing machine introduced earlier can be used to produce a batch of products. The production is triggered by an incoming customer order for a given number of products. To produce a batch, an operator needs to program the system, providing the number of products to be produced. Moreover, the system needs an IO module to provide the required bottom and top objects, and to take out the final products. The operator inspects all products. For every product that is rejected because it is misaligned, the operator programs the system to produce one more product.

(5 points) Question 3 – A Use-Case Diagram

Provide a use-case diagram for this use case, identifying relevant actors and included use cases:



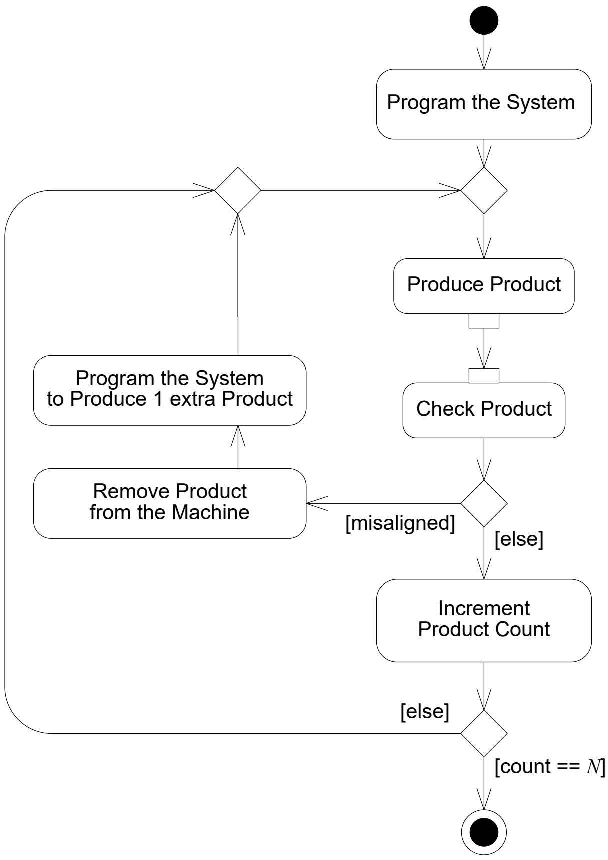
(10 points) Question 4 – A Use-Case Description

Provide a use-case description for this use case:

name:	Produce a Batch of size N
primary actor:	Operator
supporting actors:	IO Module
preconditions:	The machine is ready for production
postconditions:	N *correct* products have been produced
main scenario:	- Customer order triggers the production - Operator programs the machine to produce the required number of products - The machine produces the products - Operator inspects each produced product - For each misaligned product, the operator removes the product from the machine and programs the machine to produce one extra product
alternative scenarios:	An error may occur when the IO Module does not provide the required tops and bottoms

(15 points) Question 5 – Activity Diagram

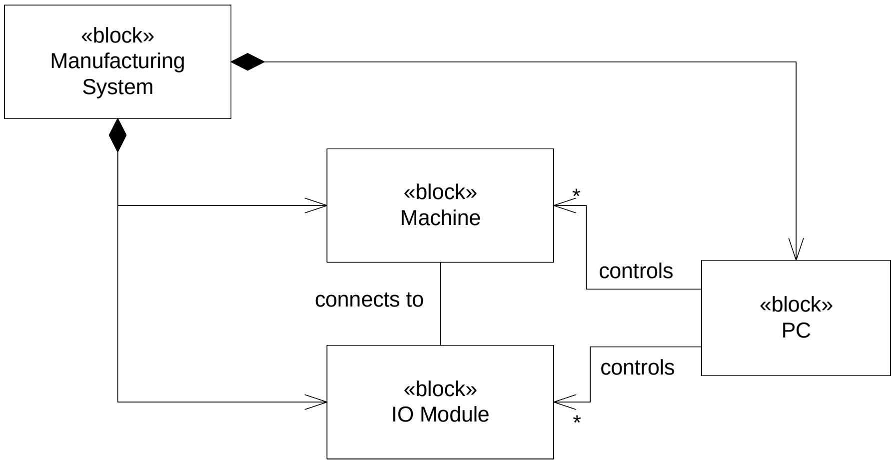
Provide an activity diagram that captures the production of a batch of N products by the operator, refining the use-case description of Question 4.

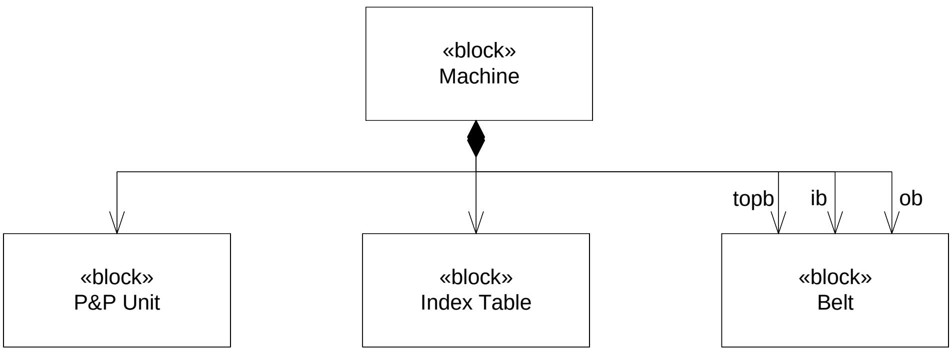


(15 points) Question 6 – Block Definition Diagram

Provide one or more block definition diagrams of the full manufacturing system, covering the base manufacturing machine, an IO module, and a PC (for programming the full system, i.e., both the IO module and the manufacturing machine). The IO module and the PC may be provided as single blocks. The IO module connects to the two belts of the manufacturing machine. The base manufacturing machine needs to be refined according to the description given at the start of this exam and consistent with the internal block diagram given in your answer to Question 1.

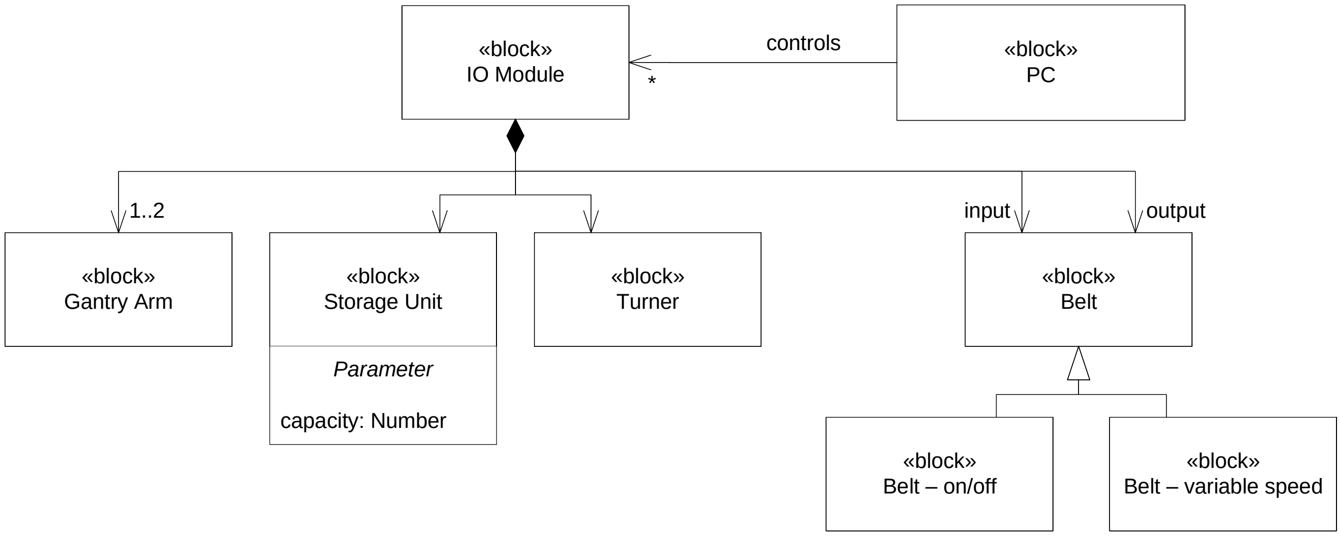
We may describe the manufacturing system with, for instance, the following two block definition diagrams.





An IO Module

The following is a block definition diagram for an IO Module for the manufacturing machine. Gantry Arms are meant for transporting objects (bottoms, tops, completed products) between any Storage Units and any Belts in the module. The Turner is used to turn bottoms or tops that are improperly oriented for assembly. The PC is a(n external) component through which the IO Module is controlled.



(5 points) Question 7 – Configurations

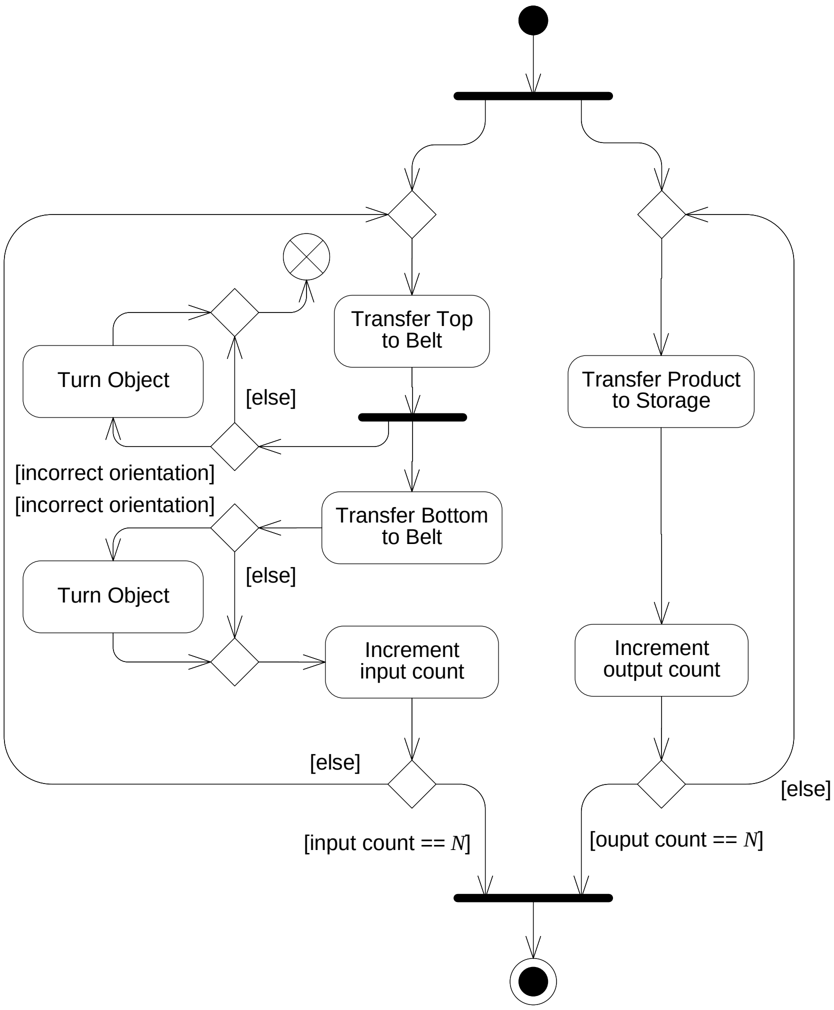
How many parts (Gantry Arms, Storage Units, Turners, Belts) does an IO Module minimally have according to this diagram? And how many does it maximally have? How many different configurations can be made for the IO Module? Motivate your answer.

The number of parts can be derived from the composite associations. An IO Module thus has at least 5 components (1 Gantry Arm, 1 Storage Unit, 1 Turner, and 2 Belts); it has at most 6 parts, namely configurations with 2 Gantry Arms. (Note that the PC is not part of the IO Module.)

8 different configuration are possible for the IO Module. It can either have 1 or 2 Gantry Arms and for each of the 2 Belts, 2 options are possible (on/off or variable speed).

Producing a Batch of Products

As already explained, the base manufacturing machine introduced earlier can be used to produce a batch of products. The following is an activity diagram that describes the IO behavior for producing a batch of N products.



(10 points) Question 8 – Allocation Matrix

Provide an allocation matrix that allocates the actions from the above activity diagram to the system parts defined by the block definition diagram for the IO Module and its controlling PC.

	Gantry Arm(s)	Storage Unit	Turner	Belts	PC
Transfer Top to Belt	x				
Transfer Bottom to Belt	x				
Turn Object			x		
Increment input count					x
Transfer Product to Storage	x				
Increment output count					x

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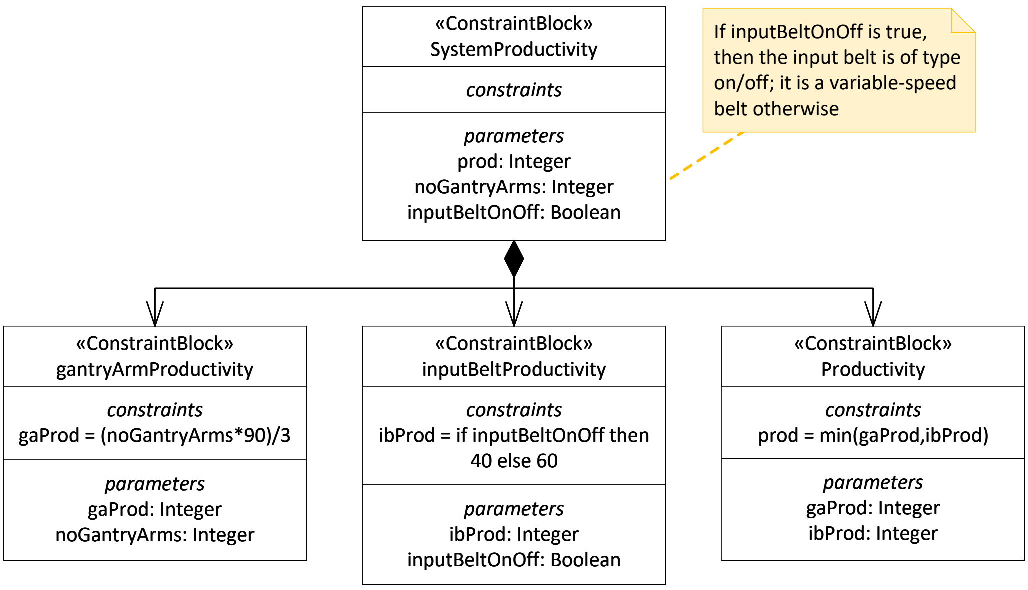
Trade offs

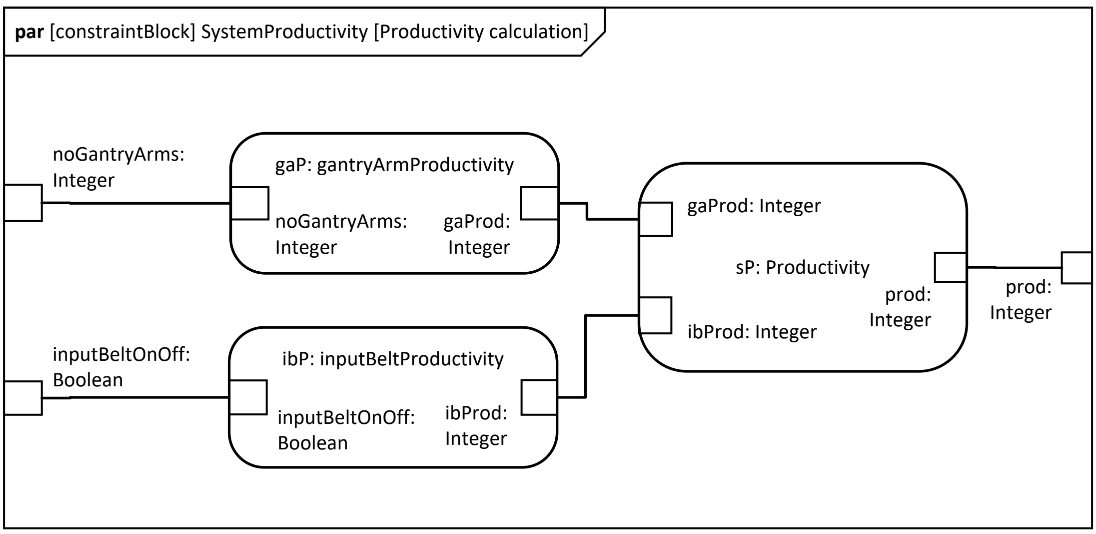
Assume that a Gantry Arm costs $30, a Storage Unit $10, a Turner $20, an on/off Belt $15, and a variable-speed Belt $20. A Gantry Arm can process 90 objects (bottoms, tops, completed products) per hour. Both Belt types can transport at most 150 objects per hour. An on/off Belt can transport 80 objects per hour when all these objects need to be turned. This applies only to a Belt transporting tops and bottoms, because these may need turning and the belt needs to be switched off during turning to avoid collisions between objects. A variable-speed Belt can transport 120 objects per hour if all objects need to be turned; it can continue operating at a lower speed when objects are being turned. *Productivity* of any specific configuration of the IO Module is defined in terms of the *minimal number of final products processed per hour*, irrespective of the orientation of the tops and bottoms that are fed into the manufacturing machine.

(10 points) Question 9 – Measures of Effectiveness

Consider the following block definition diagram for the SystemProductivity measure of effectiveness.



Provide a parametric diagram that captures the parameter bindings for the SystemProductivity measure.



(10 points) Question 10 – Trade-off Analysis

Provide a cost ($) vs. productivity trade-off analysis for implementing the IO Module according to the given block definition diagram for the module. Motivate your answer.

The input belt needs to transport twice as many objects as the output belt. This is why the output belt is not a productivity bottleneck. If one Gantry Arm is used to transport tops, bottoms, and final products, productivity is limited to at most 30 products per hour (90/3); with two Gantry Arms, productivity is limited to 60 products per hour. With one Gantry Arm, this arm is the productivity bottleneck. With two Gantry Arms, the input belt is the bottleneck. The variable-speed option for the output belt does not add productivity, because both belt types are sufficiently fast to transport (the maximum number of) 60 final products per hour.

	Input Belt	Output Belt	Cost	Productivity	Pareto optimal
1 Gantry Arm	on/off	on/off	$90	30	yes
		variable speed	$95	30	
	variable speed	on/off	$95	30	
		variable speed	$100	30	
2 Gantry Arms	on/off	on/off	$120	40	yes
		variable speed	$125	40	
	variable speed	on/off	$125	60	yes
		variable speed	$130	60	

The analysis shows that, from the eight possible configurations, only three provide optimal trade-offs between cost and productivity.

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